



# **Water Management**

## *Earth Science, Decision Support, and Societal Benefits*

### *EPA BASINS Decision Support Tool Using NASA Products*

#### **NASA-EPA-CBP Interim Meeting**

##### *Towards Verification and Validation Reporting*

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**NASA/GSFC**  
**July 14, 2006**  
*(Updated July 30, 2007)*

*Extending the societal and economic benefits of Earth science  
research, information, and technology ...*

# Project Information

## Project goal:

Assess the potential for NASA satellite and modeling *products* to improve performance of the EPA's *Decision Support System*, BASINS, used in simulating nonpoint source pollution for water quality management through the establishment of Total Daily Maximum Loads (TMDL) of pollutants

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## Project Illustration:

Integrated System Solution diagram

## Decision Support System (DSS)

BASINS has met with limited success because input data need to be obtained within the watershed and these are seldom available

The key to accurate assessments is the ability to simulate the continuous hydrograph through the HSPF hydrology model

The Chesapeake Bay uses BASINS exclusively for establishing TMDLs

End users TMDLs and can work to establish best land management practices to reduce nonpoint pollution

# Integrated Systems Solution

## Earth System Models

GSFC LIS  
LDAS  
HSPF

### Predictions and Forecasts

High Performance Computing  
Communication  
Visualization

### Standards and Interoperability

### Observations

### Observations, Parameters & Products



## Earth Observations

TRMM  
AMSR  
MODIS  
Landsat

### Decision Support Systems, Assessments, Management Actions

EPA  
BASINS  
Better Assessment Science Integrating point and Nonpoint Sources  
  
Hydrologic Simulation Program-FORTRAN

### Management Actions and Decisions

Watershed Management  
Establishing Best Management Practices  
Defining Total Maximum Daily Loads of pollutants

## Societal Benefits

Source Water Protection  
  
Storm Water Management  
  
Cleaner Water for Human, Agricultural and Industrial Consumption and Recreation and Wildlife  
  
Improved Health and Welfare  
  
Pristine Environment

# Project Products

## Demonstrations & Prototypes

Demonstrations and prototypes to show technical results and status.

Demonstrations:

- a) Default model runs using EPA techniques and data from the baseline conditions
- b) Enhanced model runs with infused NASA inputs for the same conditions as used in the default runs
- c) Statistics to measure improvements

See the following “wiring diagram” to show the system components and connections.

# V & V Components

## Verification and Validation

The V&V component to this systems engineering approach is closely connected to the evaluation and benchmarking phases:

- a) During the V&V phase, NASA data and data products are integrated into the DST to generate model outputs.
- b) To insure the quality of the output, the results are VERIFIED by comparison with model runs using in situ data as inputs - these are the default runs shown in the following tables.
- c) The next step is the VALIDATION phase in which NASA interacts with the end users (EPA) to insure that the outcome from the enhanced DST (using NASA inputs) meets the functional needs of EPA. In other words the DST is operating correctly with the NASA inputs.

# Project Products

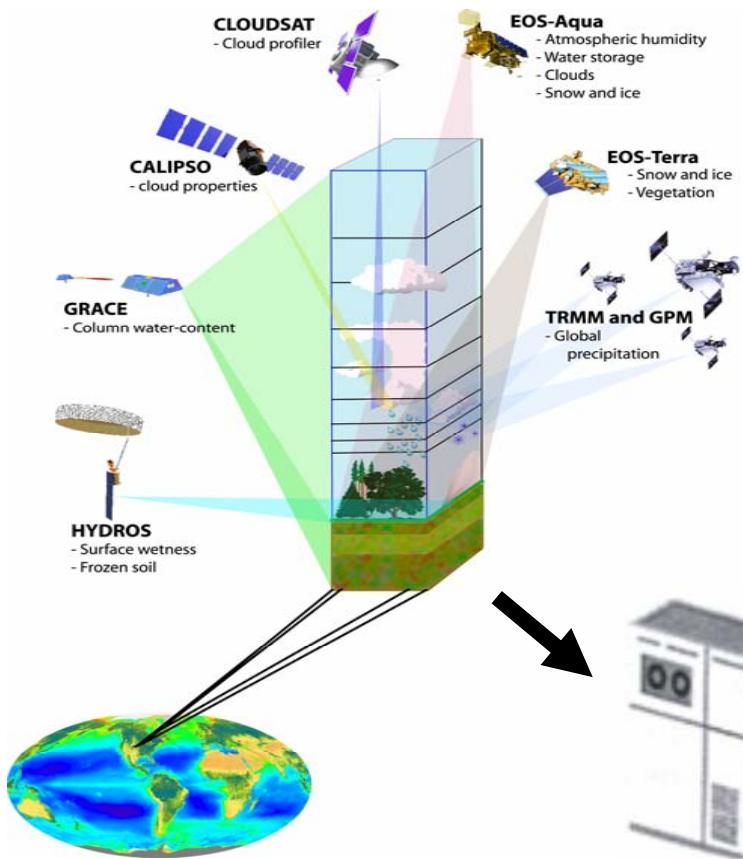
## Benchmark/Final Report

Benchmark report to address the following:

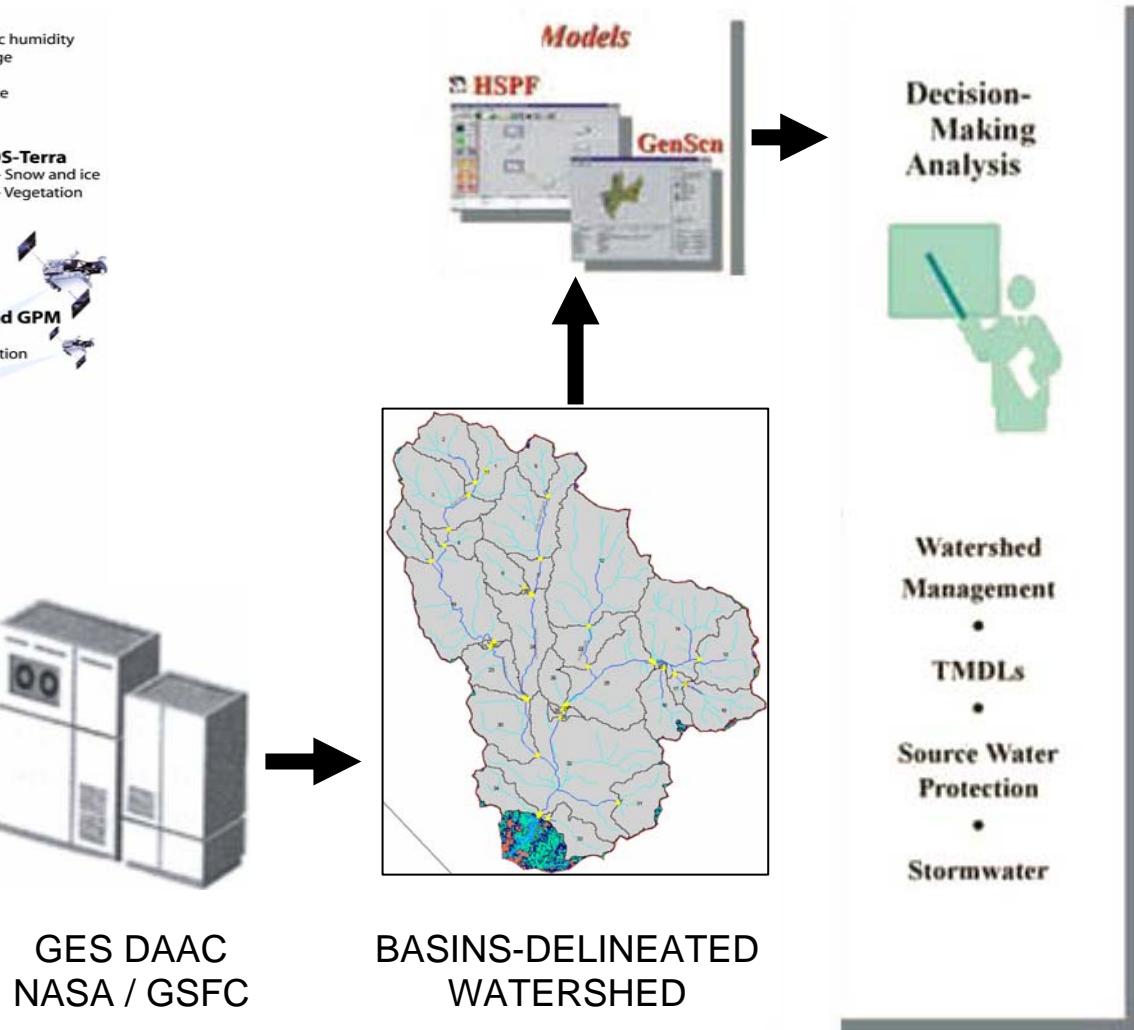
- a) Performance of the decision support system (DSS) with the Earth science results compared to DSS beforehand (Metrics are the statistics produced by BASINS-HSPF)
- b) Results of requirements analysis and issues resolved during verification and validation
- c) Issues related to transfer and adoption by the EPA
- d) Robust documentation of procedures and guidelines to describe the steps to access and utilize the Earth science research results

# BASINS “WIRING DIAGRAM”

## OBSERVATION SOURCES



## SYSTEM OVERVIEW



# EPA BASINS

**Project goal:** Assess the potential for NASA Satellite and modeling products to improve performance of the EPA BASINS Nonpoint Source Pollution model used in source water protection, and watershed management to establish Total Maximum Daily Loads of pollutants in a river.

## Major Accomplishments

Seven watersheds with varying topography and land use chosen and calibrated

LDAS and LIS data sets developed for simulation

Satellite Land Cover Phenology Completed

Evaluation report completed

## Major Milestones & Activities

Evaluation report completed

Runs with default parameters completed for all watersheds

LDAS data used as input to two watersheds

Watershed sub-divided to accept gridded LDAS and LIS data

## Risks and Mitigation

Question about use of calibrated parameters – are they reasonable?

Missing input data for default runs

BASINS watershed delineation program does not match the location of stream gauging station

## Action Items and Issues

Complete LIS data sets with stage IV precip.

Finish default runs to establish baseline conditions

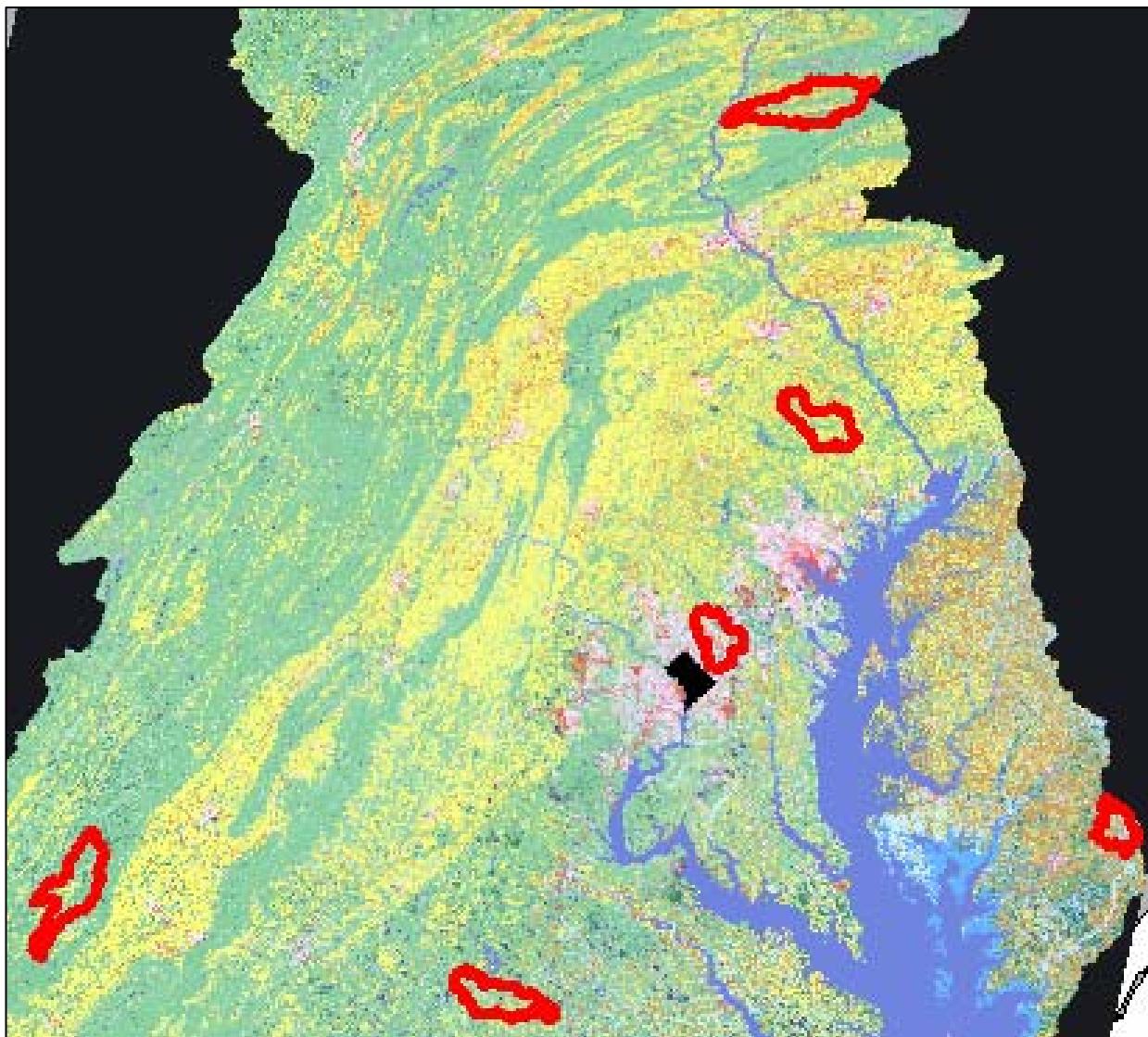
Run BASINS with NASA data and data products

Write Benchmark report

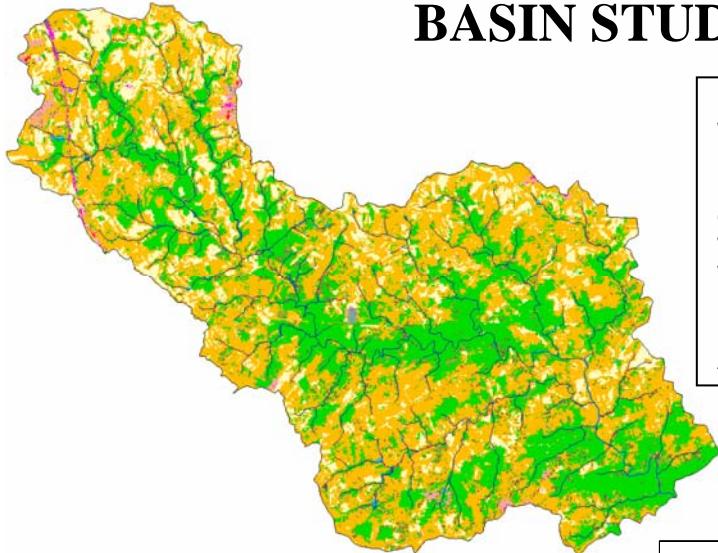
# BASIN SELECTION IN THE CHESAPEAKE BAY WATERSHED

Basins selection criteria:

1. Area between 50 – 200 square miles
2. No reservoirs
3. Presence of water quality data
4. Spatially diverse
5. Varying land cover characteristics
6. Varying terrain characteristics

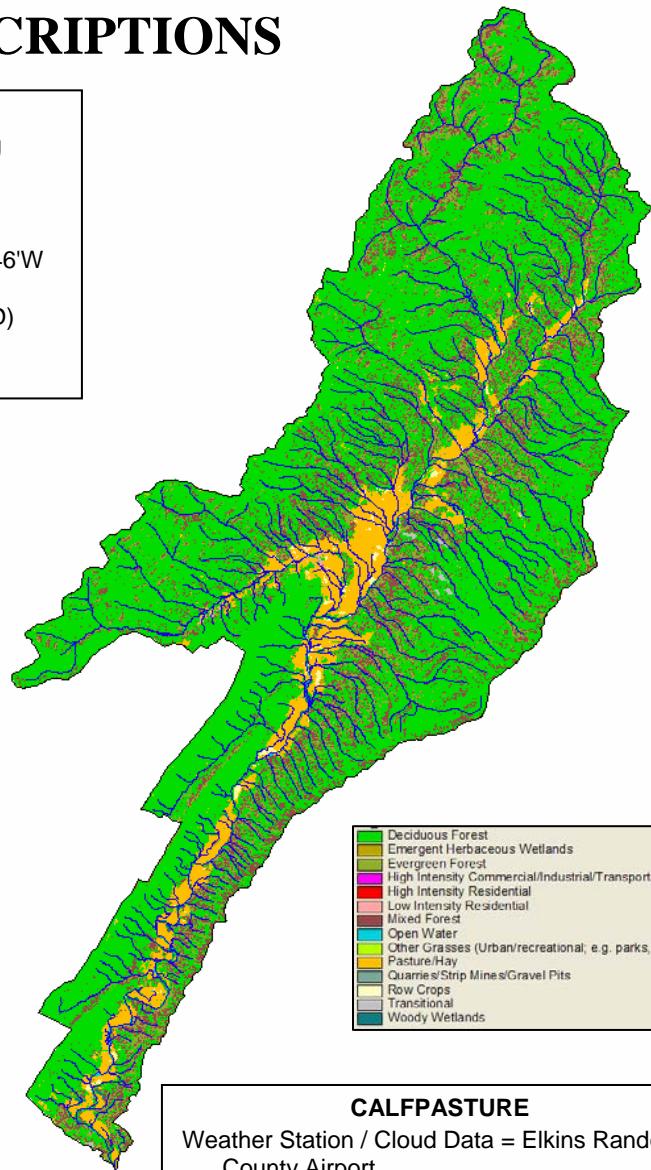


# BASIN STUDY AREAS & DESCRIPTIONS



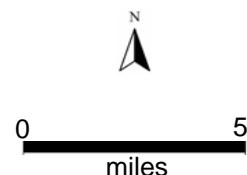
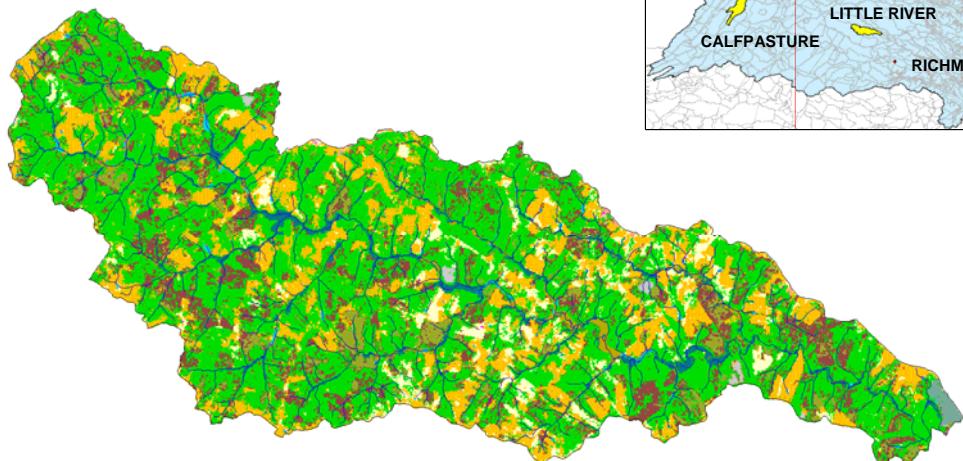
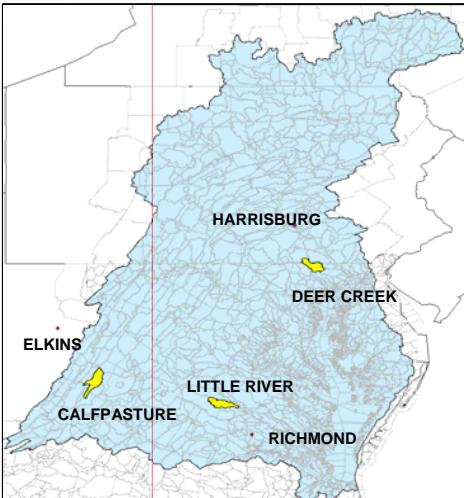
## DEER CREEK

Weather Station = Middletown Harrisburg International Airport  
Distance to Weather Station = @ 47km  
COOP ID : 365703  
Weather Station Lat/Lon = 40°12'N / 76°46'W  
Weather Station Elevation = 95.1m  
Basin Elevation = 76.26m–326.35m (NED)  
Land Cover Dataset = NLCD92  
Area of Basin = 95.53 miles<sup>2</sup>



## LITTLE RIVER

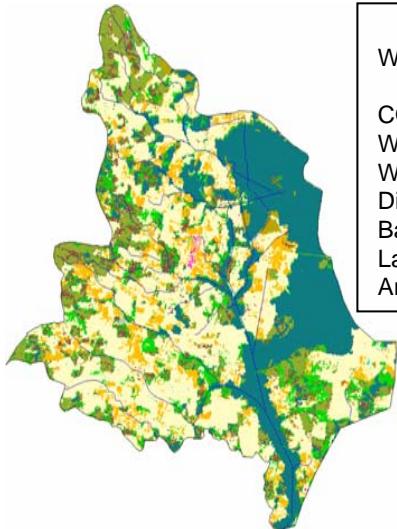
Weather Station /Cloud Data = Richmond International Airport  
Distance to Weather Station = @ 43km  
COOP ID : 447201  
Weather Station Lat/Lon = 37°30'N / 77°19'W  
Weather Station Elevation = 50m  
Basin Elevation = 36.85m–147.75m (NED)  
Land Cover Dataset = NLCD92  
Area of Basin = 106.83 miles<sup>2</sup>



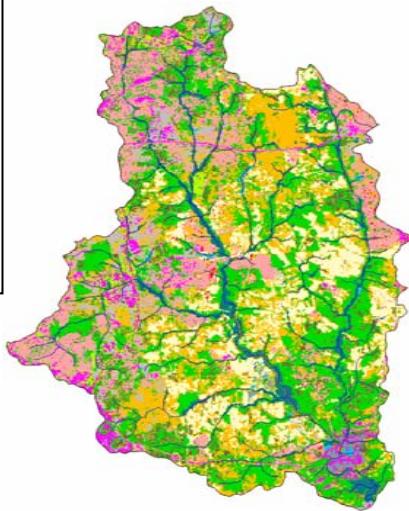
## CALFPASTURE

Weather Station / Cloud Data = Elkins Randolph County Airport  
COOP ID : 462718  
Weather Station Lat/Lon = 38°53'N / 79°51'W  
Weather Station Elevation = 603.2m  
Distance to Weather Station = @ 72km  
Basin Elevation = 408.01m–1359.80m (NED)  
Land Cover Dataset = NLCD92  
Area of Basin = 141.30 miles<sup>2</sup>

Deciduous Forest
Emergent Herbaceous Wetlands
Evergreen Forest
High Intensity Commercial/Industrial/Transportation
High Intensity Residential
Low Intensity Residential
Mixed Forest
Open Water
Other Grasses (Urban/recreational; e.g. parks, lawns)
Pasture/Hay
Quarries/Strip Mines/Gravel Pits
Row Crops
Transitional
Woody Wetlands

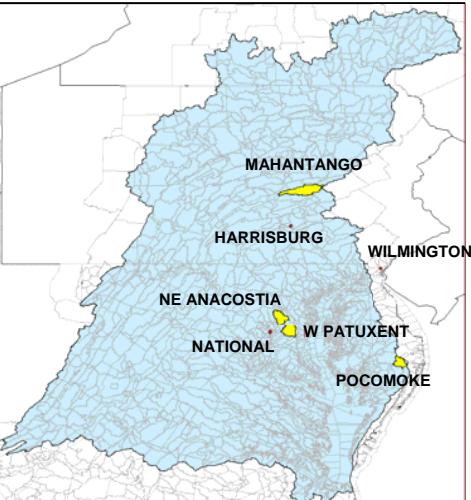
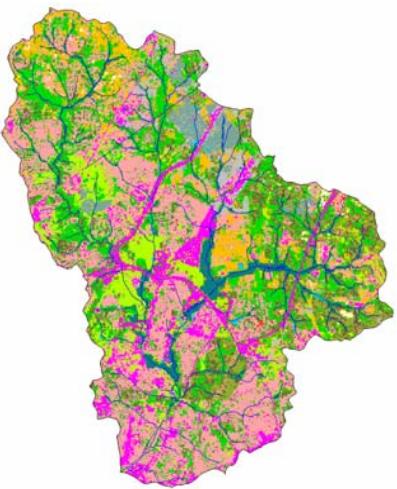


**POCOMOKE**  
Weather Station / Cloud Data = Wilmington  
New Castle County Airport  
COOP ID : 079595  
Weather Station Lat/Lon = 39°40'N / 75°36'W  
Weather Station Elevation = 24.1m  
Distance to Weather Station = @ 124km  
Basin Elevation = 5.85m–22.94m (NED)  
Land Cover Dataset = NLCD92  
Area of Basin = 55.51 miles<sup>2</sup>

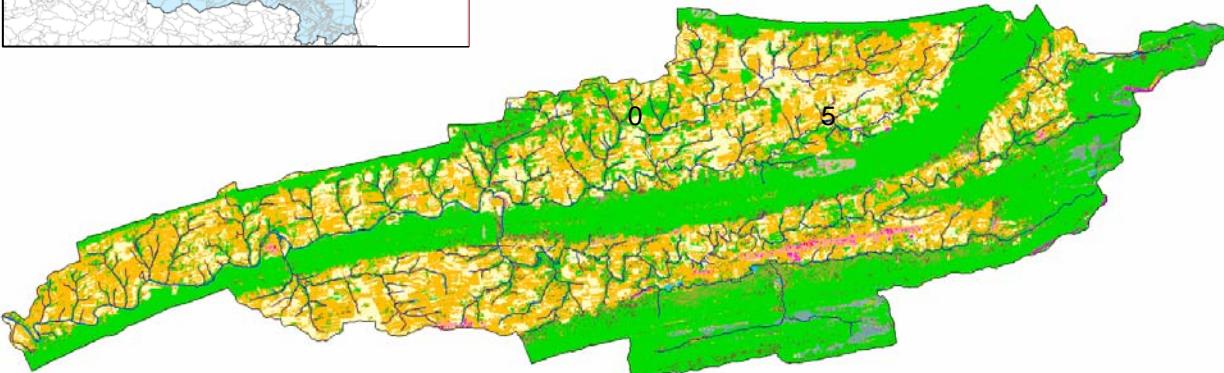


**W PATUXENT**  
Weather Station / Cloud Data = Washington  
Reagan National Airport  
COOP ID : 448906  
Weather Station Lat/Lon = 38°51'N / 77°02'W  
Weather Station Elevation = 3m  
Distance to Weather Station = @ 12km  
Basin Elevation = 0.35m–91.07m (NED)  
Land Cover Dataset = NLCD92  
Area of Basin = 93.03 miles<sup>2</sup>

Deciduous Forest
Emergent Herbaceous Wetlands
Evergreen Forest
High Intensity Commercial/Industrial/Transportation
High Intensity Residential
Low Intensity Residential
Mixed Forest
Open Water
Other Grasses (Urban/recreational; e.g. parks, lawns)
Pasture/Hay
Quarries/Strip Mines/Gravel Pits
Row Crops
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Woody Wetlands



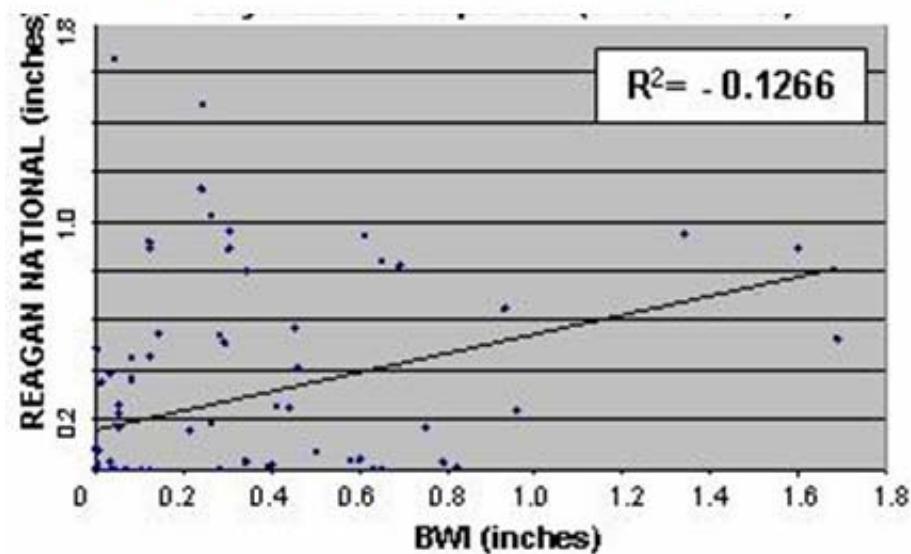
**NE ANACOSTIA**  
Weather Station / Cloud Data = Washington  
Reagan National Airport  
COOP ID : 448906  
Weather Station Lat/Lon = 38°51'N / 77°02'W  
Weather Station Elevation = 3m  
Distance to Weather Station = @ 13km  
Basin Elevation = 1.68m–170.43m (NED)  
Land Cover Dataset = NLCD92 & NLCD01  
Area of Basin = 75.01 miles<sup>2</sup>



**MAHANTANGO**  
Weather Station / Cloud Data = Middletown  
Harrisburg International Airport  
COOP ID : 365703  
Weather Station Lat/Lon = 40°12'N / 76°46'W  
Weather Station Elevation = 95.1m  
Distance to Weather Station = @ 45km  
Basin Elevation = 117.47m–554.18m (NED)  
Land Cover Dataset = NLCD92  
Area of Basin = 166.73 miles<sup>2</sup>

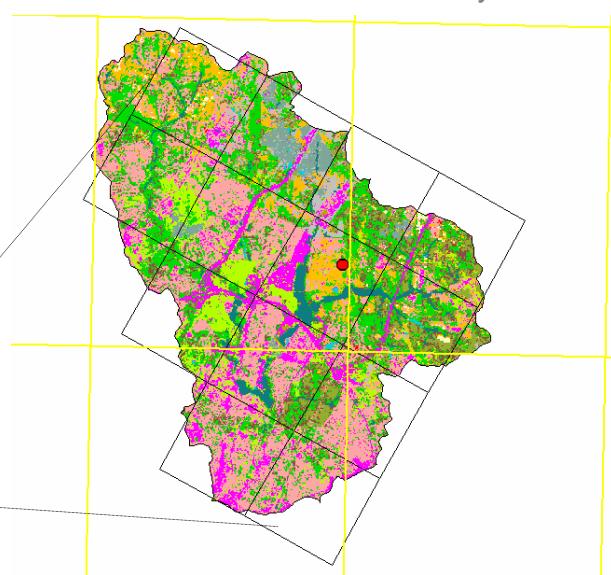
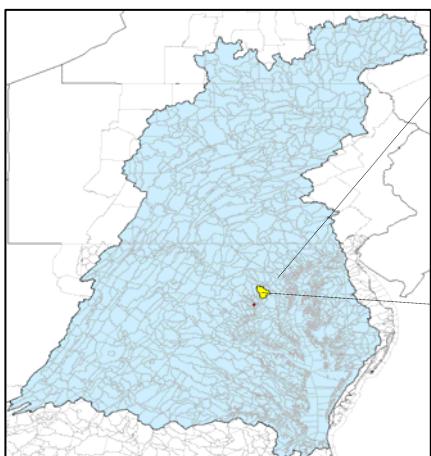
## PROBLEM WITH USING ONLY STATION PRECIPITATION

- Rain gauges (default method) not representative of precipitation events
- Satellite/Doppler spatial data complements gauge data and shows improved statistic when modeling flow at an annual level.
- More work will be done to evaluate results at more refined time periods (high & low flow)



Northeast Anacostia Study Basin

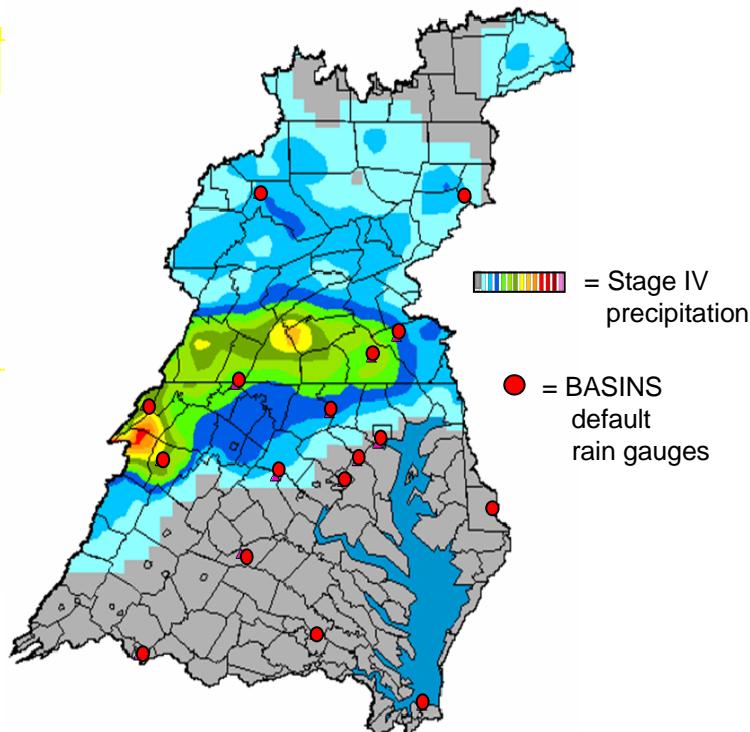
Chesapeake Bay Watershed



■ NLDAS 1/8<sup>th</sup> degree grid boundary

■ Stage IV 4km grid boundary

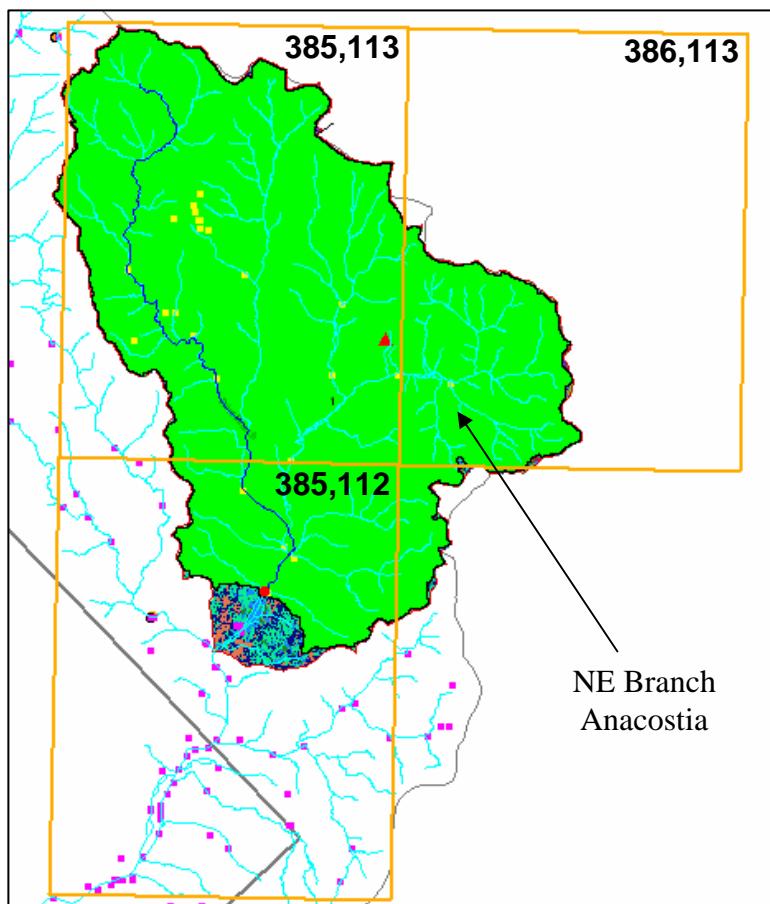
● Default weather station



■ = Stage IV precipitation

● = BASINS default rain gauges

# Adapting BASINS-HSPF for NLDAS 1/8<sup>th</sup> Degree Precipitation Data Ingestion

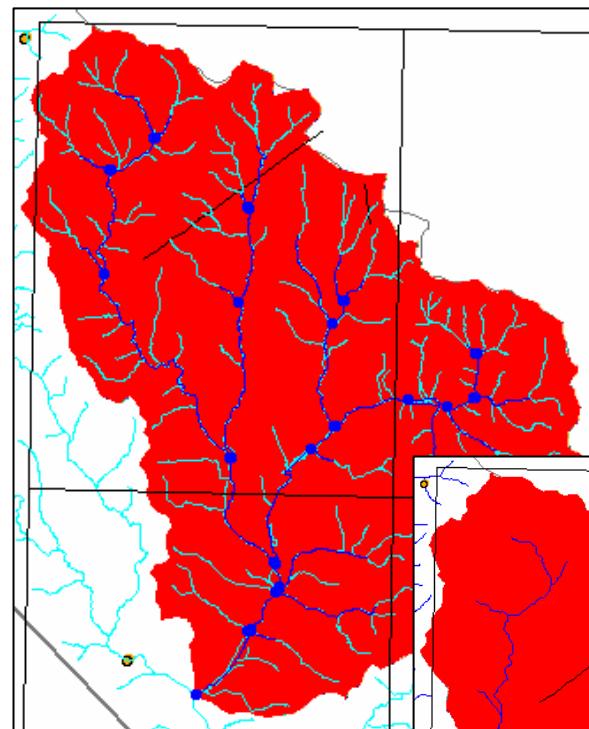


## NLDAS GRIDS:

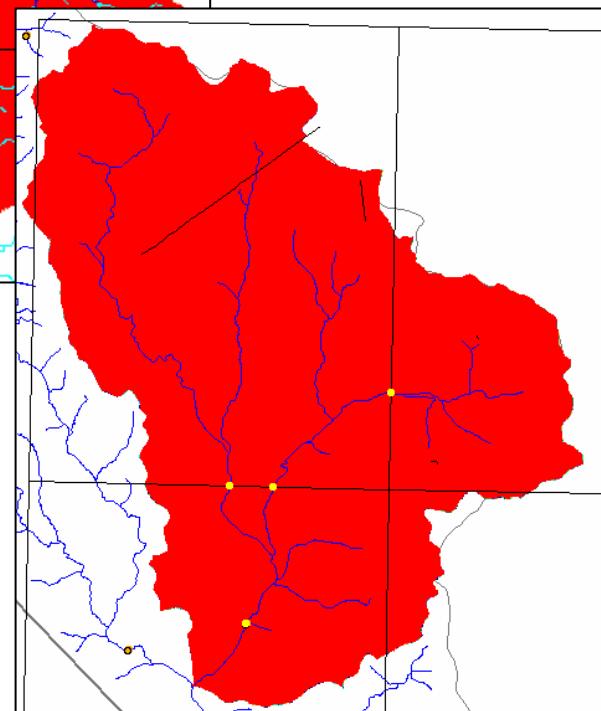
385,113

385,112

386,113



Default outlets (blue)

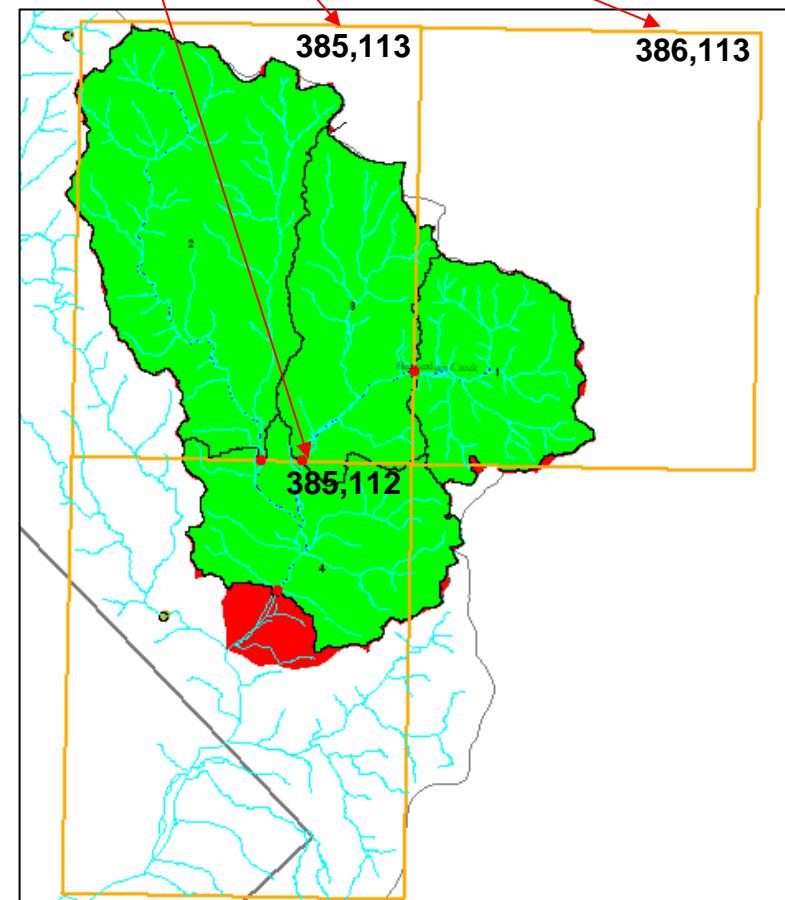
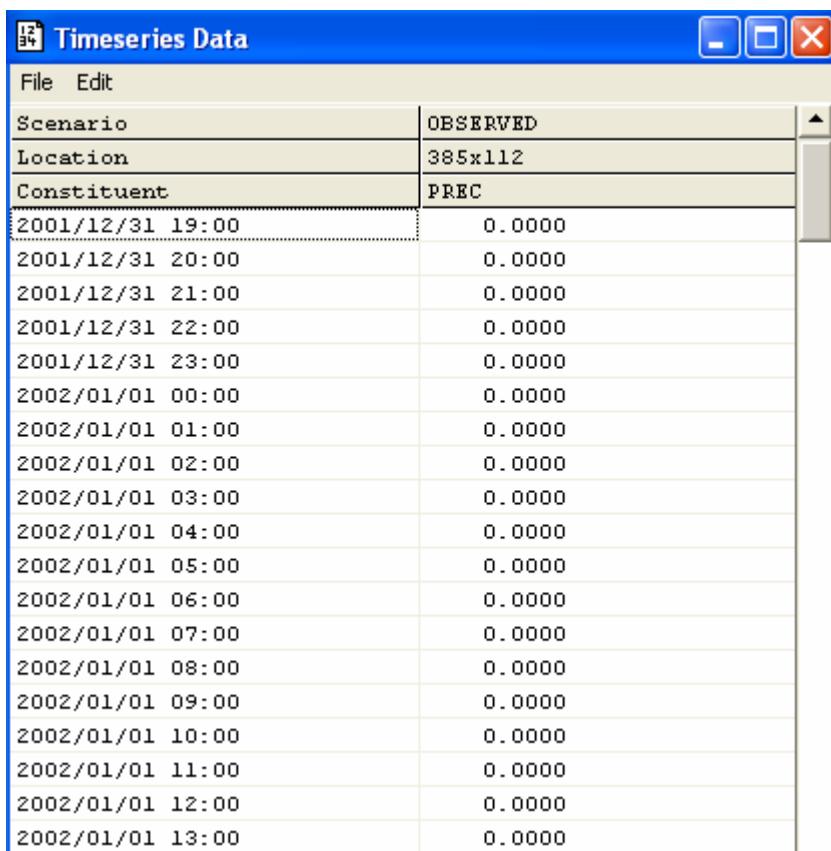


Outlets (yellow) created manually  
based on NLDAS grid

NOTE: Similar process was used for STAGE IV precipitation data

# Adapting BASINS-HSPF for NLDAS 1/8<sup>th</sup> Degree Precipitation Data Ingestion

WDM	nebranch_anacostia	19	OBSERVED	NATIONAL	TMAX	1996/1/1
WDM	nebranch_anacostia	20	OBSERVED	NATIONAL	TMIN	1996/1/1
WDM	nebranch_anacostia	2000	OBSERVED	385x112	PREC	2001/12/31
WDM	nebranch_anacostia	2001	OBSERVED	385x113	PREC	2001/12/31
WDM	nebranch_anacostia	2002	OBSERVED	386x113	PREC	2001/12/31
WDM	nebranch_anacostia	21	OBSERVED	NATIONAL	DWND	1996/1/1
WDM	nebranch_anacostia	22	OBSERVED	NATIONAL	DCLO	2000/8/1



NOTE: Similar process was used for STAGE IV precipitation data

Sample Results:

# NE Branch Anacostia Calibrated Yearly Results

• = best statistic

2001		Correlation Coefficient	Coefficient of Determination	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference	Notes	Spin-Up Time
Default		0.60	0.37	45.42	148.81	0.26		CBP	5 months
NLDAS 1/8th		0.81	0.66	35.85	99.20	0.47		CBP	5 months
Stage IV	NA	NA	NA	NA	NA	NA	NA	CBP	NA
<hr/>									
2002									
Default		0.78	0.61	32.70	78.00	0.56		CBP	17 months
NLDAS 1/8th		0.87	0.75	26.64	64.88	0.69		CBP	17 months
Stage IV	0.70	0.49	32.85	88.95	0.43			CBP	17 months
<hr/>									
2003									
Default		0.83	0.68	92.67	203.40	0.65		CBP	29 months
NLDAS 1/8th		0.80	0.65	81.73	220.32	0.59		CBP	29 months
Stage IV	0.88	0.78	84.29	193.22	0.68			CBP	29 months
<hr/>									
2004									
Default		0.60	0.36	59.00	180.42	0.32		CBP	41 months
NLDAS 1/8th		0.58	0.34	54.60	187.11	0.27		CBP	41 months
Stage IV	0.84	0.71	39.12	133.40	0.63			CBP	41 months

# Calfpsature Calibrated Yearly Results

2001		Correlation Coefficient	Coefficient of Determination	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference	Notes	Spin-Up Time
Default		0.40	0.16	97.50	187.14	0.15		CBP	0 months
NLDAS 1/8th		0.75	0.57	56.75	159.19	0.39		CBP	0 months
Stage IV	NA	NA	NA	NA	NA	NA	NA	CBP	NA
<hr/>									
2002									
Default		0.48	0.23	118.12	224.27	0.22		CBP	12 months
NLDAS 1/8th		0.60	0.36	79.92	215.08	0.28		CBP	12 months
Stage IV	0.63	0.40	83.32	225.51	0.21			CBP	12 months
<hr/>									
2003									
Default		0.54	0.29	205.01	430.16	0.09		CBP	24 months
NLDAS 1/8th		0.72	0.52	202.52	348.75	0.40		CBP	24 months
Stage IV	0.81	0.66	207.42	412.60	0.16			CBP	24 months
<hr/>									
2004									
Default		0.19	0.04	183.85	415.66	0.01		CBP	36 months
NLDAS 1/8th		0.58	0.34	107.72	352.59	0.29		CBP	36 months
Stage IV	0.50	0.25	114.40	409.41	0.04			CBP	36 months

# PROJECT STATUS SUMMARY

**D** = Downloaded

**C** = Compile

**R** = Run

✓ = completed

	NE BRANCH ANACOSTIA	CALFPASTURE	MAHANTANGO	DEER CREEK	LITTLE RIVER	W PATUXENT	POCOMOKE
<b>WEATHER DATA</b>	DCR	DCR	DCR	DCR	DCR	DCR	DCR
	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
<b>DEFAULT</b>	✓	✓	✓	✓	✓	✓	✓
<b>NLDAS 1/8<sup>th</sup></b>	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<b>STAGE IV</b>	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<b>“GEORGIA” CALIBRATION</b>	DEF1/8th ST4	DEF1/8th ST4	DEF1/8th ST4	DEF1/8th ST4	DEF1/8th ST4	DEF1/8th ST4	DEF1/8th ST4
<b>CBP COUNTY CALIBRATION</b>	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<b>PEST CALIBRATION</b>	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<b>STATISTICAL ASSESSMENT YEARLY</b>	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<b>STATISTICAL ASSESSMENT STORM PERIODS</b>	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<b>STATISTICAL ASSESSMENT LOW FLOW PERIODS</b>							

↓  
**BENCHMARK REPORT**

# BASINS/HSPF

Updated 7/07

Hunter College  
*Wenge Ni-Meister*  
*Shihyan Lee*

# Contents

- Noah ET runs
  - New data (as 04/2007) covering 01-04
  - Results
  - PEST set up
- Summary from the Past
- Discussion

# HSPF Run set-ups

- Time: 01/00 – 09/04
  - Spin-up 01/01 – 12/01
  - Calibration 01/01 – 9/04
  - Little River running at 01/01-09/04
- Spin-up use duplicated first year's data
- Scenarios
  - Default: All station data
  - N-P: NLDAS precipitation
  - N-ET: Noah ET
  - N-P ET: NLDAS precipitation and Noah ET
- Yearly Info:
  - 2001 was on the dry side of average
  - 2002 was very, very dry
  - 2003 was very, very wet
  - 2004 was on the average side of wet

# PEST Initial parameter set

- Use CBP calibration parameter as initial condition improve the results.
- Use PEST half-way calibrated parameters as initial condition yield similar results. (as suggested by Angelica from 03/07 meeting)
- Is this a fair initial parameter set? Since CBP is calibrating against station data.

Mean=156.32, GMean = 95. Running 2002/10-2004/9 at West Branch

Use NLDAS P and station PET

	Mean	GMean	R	Mean Error%	RMSE	E(NS)
Default	153.71	94.33	0.78	-1.7	137.46	0.58
Run 1	153.63	94.41	0.75	-1.75	145.46	0.53
Run 2	153.91	94.69	0.84	-1.56	115	0.7

# PEST calibration

- Strategy
  - Follow suggestions in EPA HSPF calibration guide (technical doc 6).
  - Calibrate 11 parameters
    - Calibrate additional impervious land parameters (2 of them) if large urban area exists (NE Anacostia)
  - No monthly variation
  - Calibrate only dominate landuse type
    - Technical difficulty (worse results when more landuse types were calibrated separately)
- Components of objective functions
  - mflow, daily flow with weight adjusted to focus on base (low) flow
  - mvol, monthly flow
  - mtime, exceedence time
- Additional component to for Noah ET runs
  - mET, daily ET.
- The goal was to make each components contribute roughly the same amount at the end of calibration, at the same time not over weighting certain component just because it is the easiest for improvement.
- Use CBP calibration parameters as initial condition.
- Use the most current version of PEST (v11).

# Summary from the past

- Mosaic ET vs. Noah ET
  - Noah ET should be better for the Northeast. Mosaic ET tend to over estimate
- NLDAS P, Noah ET
  - Running 02-03 (all 7 basins)
  - Calibration
    - Calibrate all parameters recommended by EPA
    - Add ET as part of objective function and match HSPF ET and N-ET during calibration.
- Calibration objective functions analysis
  - mtime – most sensitive
  - mET – least sensitive
- NLDAS P, Noah ET
  - Running 01-04 (all 7 basins)
  - Calibration
    - Calibrate all parameters recommended by EPA
    - Add ET as part of objective function and match HSPF ET and N-ET during calibration.
    - Use the updated PEST (v11)
    - Use CBP calibration parameters as the initial parameters set.

# Summary from the past

- Pilot:
  - 02-03 at Pat and Ana.
- NLDAS P, and Mosaic ET
  - Running 01-04 (Ana, Pat, Mahan, and Calf)
  - Calibration
    - Default PEST calibration set by winHSPF
    - Use LZETP=1 to match HSPF ET and N-ET
  - Segmentation at Calf.
    - Yield almost identical results.
  - NLDAS precipitation issues
    - First run: use only liquid form (rain)
    - Following runs:  $P = \text{rain} + \text{snow melt}$
  - Statistics
    - Modified model fit efficiency.
    - Which parameters should we use?
  - Geographical differences
    - Weather station vs. Watershed
    - Best performance on each watershed does not vary a lot.
    - Station data (Good vs. Bad) based on its geographical differences.

# Results

- The accumulated results so far:
  - Some improvements can be made by NLDAS P
  - No major difference when Noah or NLDAS ET was used.
  - Most improvement are made at the basins which the default performed badly.

# Overall Performance and by Year

West Branch								
01-Jan-2001 to 30-Sep-2004								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	103.11	0.81	-6.4	40.43	101.28	0.66	0.54	
N-P	106.46	0.83	-3.37	37.51	98.02	0.68	0.57	
N-ET	100.18	0.8	-9.06	42.2	104.12	0.64	0.52	
N-P ET	106.09	0.82	-3.69	40.46	101.07	0.66	0.54	0.97
01-Jan-2001 to 01-Dec-2001								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	58.86	0.77	-23.24	41.5	72.81	0.54	0.47	
N-P	63.37	0.77	-17.36	41.14	69.83	0.58	0.48	
N-ET	69.69	0.78	-9.12	43.86	67.92	0.6	0.44	
N-P ET	65.28	0.76	-14.87	45.02	70.71	0.56	0.43	0.98
01-Jan-2002 to 01-Dec-2002								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	54.44	0.82	18.27	55.04	46.86	0.64	0.42	
N-P	45.72	0.83	-0.67	47.49	44.43	0.68	0.5	
N-ET	51.37	0.8	11.6	55.58	47.91	0.63	0.41	
N-P ET	46.32	0.82	0.61	51.2	45.46	0.66	0.46	0.94
01-Jan-2003 to 01-Dec-2003								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	187.57	0.81	0.29	36.36	145.95	0.66	0.54	
N-P	194.42	0.8	3.95	36.35	152.51	0.63	0.54	
N-ET	178.28	0.83	-4.68	35.62	141.55	0.68	0.55	
N-P ET	190.8	0.82	2.02	35.24	141.86	0.68	0.55	0.99
01-Jan-2004 to 30-Sep-2004								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	96.81	0.71	-19.37	43.96	115.15	0.49	0.37	
N-P	109.48	0.81	-8.81	35.49	94.09	0.66	0.49	
N-ET	91.81	0.61	-23.54	48.91	130.66	0.34	0.3	
N-P ET	115.8	0.71	-3.55	47.32	123.83	0.41	0.33	0.98

NE Anascotia								
01-Jan-2001 to 30-Sep-2004								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	103.38	0.8	-4.15	47.14	137.9	0.64	0.52	
N-P	100.39	0.81	-6.93	44.39	135.78	0.65	0.54	
N-ET	98.97	0.8	-8.24	48.26	136.33	0.64	0.5	
N-P ET	96.52	0.83	-10.51	43.19	130.1	0.68	0.56	0.95
01-Jan-2001 to 01-Dec-2001								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	63.04	0.68	-12.04	50.53	104.47	0.45	0.46	
N-P	60.21	0.79	-16	50.19	87.08	0.62	0.46	
N-ET	64.84	0.8	-9.53	51.16	85.22	0.64	0.45	
N-P ET	65.87	0.8	-8.09	52.37	85.73	0.63	0.44	0.91
01-Jan-2002 to 01-Dec-2002								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	61.66	0.8	24.24	56.1	70.6	0.52	0.43	
N-P	66.06	0.86	33.1	59.9	62.66	0.62	0.39	
N-ET	58.05	0.79	16.98	59.16	72.61	0.49	0.4	
N-P ET	58.67	0.85	18.21	55.16	60.23	0.65	0.44	0.96
01-Jan-2003 to 01-Dec-2003								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	176.72	0.85	-7.32	42.81	181.57	0.73	0.54	
N-P	169.03	0.85	-11.35	37.96	186.23	0.71	0.59	
N-ET	171.46	0.85	-10.08	43.25	185.01	0.71	0.53	
N-P ET	165.85	0.87	-13.02	36.39	180.31	0.73	0.61	0.97
01-Jan-2003 to 01-Dec-2003								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	176.72	0.85	-7.32	42.81	181.57	0.73	0.54	
N-P	169.03	0.85	-11.35	37.96	186.23	0.71	0.59	
N-ET	171.46	0.85	-10.08	43.25	185.01	0.71	0.53	
N-P ET	165.85	0.87	-13.02	36.39	180.31	0.73	0.61	0.97
01-Jan-2004 to 30-Sep-2004								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	103.43	0.65	-9.1	52.31	176.42	0.35	0.37	
N-P	88.73	0.61	-22.02	46.9	176.22	0.35	0.43	
N-ET	97.07	0.64	-14.69	52.89	174.56	0.36	0.36	
N-P ET	83.99	0.65	-26.18	47.45	169.48	0.4	0.43	0.96

# Overall Performance and by Year

Mahantango								
01-Jan-2001 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	233.54	0.69	-7.69	54.08	299.14	0.48	0.3	
N-P	240.01	0.88	-5.13	38.36	206.14	0.75	0.5	
N-ET	235.37	0.7	-6.96	55.96	296.25	0.49	0.28	
N-P ET	242.03	0.89	-4.33	41.62	192.9	0.78	0.46	0.88
01-Jan-2001 to 01-Dec-2001								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	91.1	0.81	-32.01	47.25	95.49	0.53	0.41	
N-P	113.36	0.72	-15.4	47.66	104.38	0.44	0.4	
N-ET	118.87	0.7	-11.29	50.79	106.51	0.41	0.36	
N-P ET	115.53	0.72	-13.79	48.28	104.52	0.44	0.39	0.69
01-Jan-2002 to 01-Dec-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	175.32	0.85	14.67	37.74	93.81	0.7	0.51	
N-P	178.46	0.8	16.72	43.63	117.41	0.53	0.43	
N-ET	166.22	0.85	8.72	35.37	92.92	0.71	0.54	
N-P ET	163.97	0.76	7.25	49.88	118.75	0.52	0.35	0.89
01-Jan-2003 to 01-Dec-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	327.97	0.44	-11.47	53.72	341.06	0.16	0.22	
N-P	344.3	0.82	-7.07	34.82	219.45	0.65	0.49	
N-ET	335.94	0.41	-9.32	56.32	350.84	0.11	0.18	
N-P ET	363.02	0.82	-2.01	35.82	211.78	0.68	0.48	0.99
01-Jan-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	334.13	0.73	1.02	69.58	483.48	0.52	-0.06	
N-P	304.9	0.91	-7.82	38.52	317.37	0.79	0.41	
N-ET	324.86	0.76	-1.78	71.84	455.96	0.57	-0.1	
N-P ET	316.1	0.93	-4.43	44.7	275.92	0.84	0.32	0.99

Calfpasture								
01-Jan-2001 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	135.52	0.44	-25.6	73.88	322.54	0.17	0.29	
N-P	159.79	0.81	-12.28	48.76	213.02	0.64	0.53	
N-ET	173.72	0.36	-4.63	90.01	359.75	-0.03	0.13	
N-P ET	147.63	0.76	-18.95	53.2	237.29	0.55	0.49	0.99
01-Jan-2001 to 01-Dec-2001								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	74.3	0.52	-28.4	75.12	182.97	0.24	0.32	
N-P	61.34	0.83	-40.88	49.01	135.53	0.58	0.56	
N-ET	154	0.36	48.41	125.62	277.78	-0.74	-0.13	
N-P ET	68.21	0.85	-34.27	57.16	137.46	0.57	0.49	1
01-Jan-2002 to 01-Dec-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	126.66	0.65	21.22	73.73	176.05	0.39	0.35	
N-P	79.58	0.82	-23.83	53.57	140.39	0.61	0.53	
N-ET	184.74	0.59	76.82	107.98	257.29	-0.31	0.05	
N-P ET	67.43	0.76	-35.46	56.36	162.92	0.47	0.51	0.95
01-Jan-2003 to 01-Dec-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	150.29	0.51	-53	70.39	426.55	0.11	0.22	
N-P	300.79	0.81	-5.93	46.62	270.64	0.64	0.48	
N-ET	163.49	0.57	-48.87	68.51	402.84	0.21	0.24	
N-P ET	291.31	0.78	-8.89	48.35	291.51	0.58	0.46	1
01-Jan-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	196.72	0.25	6.79	87.5	424.42	-0.03	0.03	
N-P	178.28	0.79	-3.22	49.33	262.93	0.6	0.45	
N-ET	229.88	0.22	24.79	105.79	468.13	-0.26	-0.17	
N-P ET	158.13	0.68	-14.16	62.08	307.94	0.46	0.31	1

# Overall Performance and by Year

Pocomoke								
01-Jan-2001 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	77.08	0.42	-13.27	68.53	114.23	0.06	0.2	
N-P	81.6	0.88	-8.19	38.83	57.67	0.76	0.55	
N-ET	76.31	0.45	-14.15	65.79	110.23	0.13	0.23	
N-P ET	78.78	0.84	-11.36	40	65.22	0.69	0.53	0.7
01-Jan-2001 to 01-Dec-2001								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	47.3	0.47	-22.84	62.14	74.2	0.02	0.24	
N-P	62.5	0.88	1.96	36.3	39.49	0.72	0.56	
N-ET	51.37	0.49	-16.2	62.53	74.57	0.01	0.24	
N-P ET	64.33	0.81	4.94	44.79	47.92	0.59	0.45	0.63
01-Jan-2002 to 01-Dec-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	45.93	0.51	-14.82	65.52	75.62	0.25	0.32	
N-P	69.89	0.87	29.61	52.91	48.4	0.69	0.45	
N-ET	51.15	0.61	-5.16	65	69.21	0.37	0.33	
N-P ET	67.06	0.85	24.36	48.84	50.19	0.67	0.49	0.47
01-Jan-2003 to 01-Dec-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	106.44	0.38	-21.85	59.74	143.13	-0.03	0.17	
N-P	108.13	0.91	-20.61	32.39	68.7	0.76	0.55	
N-ET	102.29	0.39	-24.9	59.35	140.88	0	0.18	
N-P ET	105.07	0.9	-22.85	31.91	77.6	0.7	0.56	0.77
01-Jan-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	112.07	0.14	35.03	107.26	138.96	-0.69	-0.41	
N-P	77.46	0.85	-6.68	44.35	56.45	0.72	0.42	
N-ET	98.82	0.16	19.05	94.21	130.18	-0.48	-0.23	
N-P ET	70.27	0.81	-15.34	46.11	64.49	0.64	0.4	0.85

Deer Creek								
01-Jan-2001 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	125.05	0.55	-4.09	46.26	122.05	0.22	0.27	
N-P	127.55	0.79	-2.16	33.15	84.53	0.62	0.47	
N-ET	113.74	0.56	-12.76	46.03	115.7	0.3	0.27	
N-P ET	126.13	0.74	-3.25	38.77	94.84	0.53	0.38	0.87
01-Jan-2001 to 01-Dec-2001								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	45.67	0.78	-42.86	42.9	56.56	0.19	0.18	
N-P	50.77	0.73	-36.47	39.89	54.3	0.25	0.24	
N-ET	42.91	0.72	-46.32	47.83	60.61	0.07	0.09	
N-P ET	56.59	0.76	-29.2	36.76	47.79	0.42	0.3	0.84
01-Jan-2002 to 01-Dec-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	81.97	0.64	81.89	92.22	56.27	-1.2	-0.78	
N-P	64.49	0.74	43.12	63.02	35.94	0.1	-0.22	
N-ET	81.82	0.63	81.56	95.33	56.87	-1.25	-0.84	
N-P ET	73.02	0.72	62.04	81.01	54.95	-1.1	-0.56	0.82
01-Jan-2003 to 01-Dec-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	188.63	0.57	-7.09	31.88	121.76	0.31	0.27	
N-P	206.58	0.79	1.75	24.57	92.39	0.6	0.43	
N-ET	177.14	0.45	-12.75	32.73	133.69	0.17	0.25	
N-P ET	196.49	0.72	-3.22	29.42	105.91	0.48	0.32	0.9
01-Jan-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	185.35	0.32	-5.42	54.31	202.67	-0.57	-0.33	
N-P	177.35	0.7	-9.51	28.15	116.36	0.48	0.31	
N-ET	156.57	0.27	-20.11	48.11	164.5	-0.04	-0.18	
N-P ET	172.17	0.65	-12.15	36.54	127.3	0.38	0.1	0.87

# Overall Performance and by Year

Little River								
01-Jan-2002 to 30-Sep-2004								
Scenario	Mean	R	%M error	%M abs	RMSE	E	E1	R(ET)
Default	95.11	0.43	-15.26	69.79	177.83	0.13	0.24	
N-P	108.69	0.72	-3.16	47.85	134.67	0.5	0.48	
N-ET	106.64	0.42	-4.99	71.31	189.05	0.01	0.22	
N-P ET	106.02	0.75	-5.55	42.81	128.99	0.54	0.53	0.99
01-Jan-2002 to 01-Dec-2002								
Scenario	Mean	R	%M error	%M abs	RMSE	E	E1	R(ET)
Default	27.58	0.75	3.55	64.07	34.85	0.56	0.34	
N-P	24.36	0.89	-8.57	56.3	24.8	0.78	0.42	
N-ET	16.86	0.79	-36.69	55.67	39.7	0.43	0.43	
N-P ET	24.34	0.9	-8.63	53.82	25.25	0.77	0.45	0.97
01-Jan-2003 to 01-Dec-2003								
Scenario	Mean	R	%M error	%M abs	RMSE	E	E1	R(ET)
Default	134.83	0.52	-23.17	58.96	225.93	0.24	0.31	
N-P	179.59	0.68	2.33	43.48	198.34	0.42	0.49	
N-ET	158.74	0.51	-9.55	60.48	223.95	0.26	0.29	
N-P ET	184.78	0.7	5.29	41.2	193.96	0.44	0.52	1
01-Jan-2004 to 30-Sep-2004								
Scenario	Mean	R	%M error	%M abs	RMSE	E	E1	R(ET)
Default	128.56	0.13	13.94	95.71	190.1	-1.75	-0.59	
N-P	109.72	0.63	-2.75	58.54	98.2	0.27	0.03	
N-ET	150.13	0.13	33.06	105.4	233.36	-3.14	-0.75	
N-P ET	89.29	0.74	-20.86	46.11	80.92	0.5	0.24	1

# Performance during Summer 7/1-9/30

West Branch								
01-Jul-2001 to 30-Sep-2001								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	49.62	0.67	-18.56	49.6	61.82	0.42	0.38	
N-P	57.29	0.53	-5.98	55.29	72.22	0.21	0.3	
N-ET	59.74	0.68	-1.94	56.31	59.88	0.46	0.29	
N-P ET	69.39	0.43	13.9	66.5	86.04	-0.12	0.16	0.89
01-Jul-2002 to 30-Sep-2002								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	22.73	0.66	39.32	92.61	32.88	0.23	0.22	
N-P	24.1	0.8	47.71	83.28	31.58	0.29	0.3	
N-ET	20.06	0.62	22.95	86.31	33.33	0.2	0.27	
N-P ET	29.17	0.82	78.78	99.4	32.01	0.27	0.16	0.84
01-Jul-2003 to 30-Sep-2003								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	148.27	0.85	-3.03	35.82	115.17	0.72	0.54	
N-P	153.65	0.89	0.49	33.49	103.33	0.77	0.57	
N-ET	156.3	0.86	2.22	37.54	109.47	0.75	0.52	
N-P ET	174.93	0.88	14.41	40.84	106.68	0.76	0.48	0.97
01-Jul-2004 to 30-Sep-2004								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	104.44	0.62	1.03	60.12	127.63	0.34	0.33	
N-P	84.91	0.77	-17.87	43.96	104.1	0.56	0.51	
N-ET	113.72	0.61	10	64.51	133.15	0.28	0.28	
N-P ET	106.37	0.78	2.89	47.34	102.91	0.57	0.47	0.92

NE Anascotia								
01-Jul-2001 to 30-Sep-2001								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	65.8	0.54	-2.21	64.14	109.79	0.24	0.37	
N-P	61.64	0.49	-8.38	71.62	110.9	0.23	0.3	
N-ET	64.43	0.49	-4.24	72.41	110.81	0.23	0.29	
N-P ET	64.43	0.49	-4.24	72.41	110.81	0.23	0.29	0.85
01-Jul-2002 to 30-Sep-2002								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	38.19	0.7	19.19	73.18	68.7	0.36	0.38	
N-P	49.71	0.77	55.13	84.39	63.07	0.46	0.29	
N-ET	39.06	0.68	21.91	78.56	70.09	0.33	0.34	
N-P ET	43.32	0.76	35.2	69.67	61.8	0.48	0.41	0.93
01-Jul-2003 to 30-Sep-2003								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	163.7	0.8	-4.64	58.93	227.92	0.65	0.36	
N-P	125.8	0.83	-26.72	53.24	267.04	0.51	0.42	
N-ET	176.51	0.77	2.82	60.99	245.24	0.59	0.34	
N-P ET	143.56	0.84	-16.37	53.3	254.19	0.56	0.42	0.92
01-Jul-2004 to 30-Sep-2004								
Scenario	Mean	R	%M err	%M abs	RMSE	E	E1	R(ET)
Default	131.25	0.59	-6.69	67.18	282.66	0.26	0.39	
N-P	79.87	0.66	-43.22	59.82	279.12	0.28	0.45	
N-ET	133.32	0.59	-5.22	65.66	277.18	0.29	0.4	
N-P ET	86.91	0.67	-38.21	58.98	275.54	0.3	0.46	0.9

# Performance during Summer 7/1-9/30

Mahantango								
01-Jul-2001 to 30-Sep-2001								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	50.31	0.56	-14.86	41.43	51.99	0.27	0.32	
N-P	91.14	0.55	54.24	94.31	130.15	-3.57	-0.56	
N-ET	91.14	0.55	54.24	94.31	130.15	-3.57	-0.56	
N-P ET	91.14	0.55	54.24	94.31	130.15	-3.57	-0.56	0.44
01-Jul-2002 to 30-Sep-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	52.01	0.76	48.28	89.9	57.1	0.47	-0.04	
N-P	80.59	0.9	129.77	134.29	128.67	-1.68	-0.55	
N-ET	33.82	0.76	-3.56	56.93	51.55	0.57	0.34	
N-P ET	55.43	0.87	58.03	69.52	52.31	0.56	0.2	0.74
01-Jul-2003 to 30-Sep-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	283.79	0.28	-19.09	65.55	425.31	-0.03	0.15	
N-P	341.26	0.84	-2.71	41.06	239.26	0.67	0.47	
N-ET	298.22	0.25	-14.98	68.16	436.69	-0.08	0.12	
N-P ET	414.4	0.92	18.14	39.07	181.94	0.81	0.5	0.97
01-Jul-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	575.83	0.8	61.01	109.38	778.41	0.55	-0.01	
N-P	427.37	0.93	19.5	51.46	510	0.81	0.53	
N-ET	607.32	0.83	69.81	111.98	723.98	0.61	-0.03	
N-P ET	475.99	0.96	33.09	55.02	416.91	0.87	0.49	0.98

Calfpasture								
01-Jul-2001 to 30-Sep-2001								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	52.33	0.04	136.79	206.47	78.32	-2.95	-1.26	
N-P	25.38	0.24	14.82	88.93	47.32	-0.44	0.03	
N-ET	192.08	-0.01	769.09	841.25	379.86	-91.92	-8.21	
N-P ET	48.18	0.52	117.99	140.92	53.79	-0.86	-0.54	0.99
01-Jul-2002 to 30-Sep-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	23.4	0.52	156.15	188.31	25.68	-3.24	-1.08	
N-P	20.13	0.83	120.38	124.97	26.42	-3.49	-0.38	
N-ET	113.77	0.37	1145.3	1166.7	276.94	-491.94	-11.88	
N-P ET	16.58	0.81	81.5	96.49	11.3	0.18	-0.07	0.89
01-Jul-2003 to 30-Sep-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	26.32	0.7	-86.64	86.64	392.58	-0.09	0.17	
N-P	245.4	0.8	24.55	62.22	233.24	0.62	0.4	
N-ET	114.46	0.61	-41.91	77.34	310.66	0.32	0.26	
N-P ET	286.06	0.8	45.19	74.31	251.41	0.55	0.29	1
01-Jul-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	41.89	-0.11	-78.36	92.91	662.93	-0.07	0.31	
N-P	175.43	0.81	-9.37	62.59	404.67	0.6	0.53	
N-ET	129.04	0.02	-33.34	117.93	673	-0.1	0.12	
N-P ET	222.43	0.69	14.91	80.32	467.71	0.47	0.4	1

# Performance during Summer 7/1-9/30

Pocomoke								
01-Jul-2001 to 30-Sep-2001								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	13.57	-0.1	-63.57	76.92	64.6	-0.23	0.02	
N-P	56.86	0.96	52.65	60.02	50.7	0.24	0.24	
N-ET	12.04	-0.09	-67.68	75	64.61	-0.23	0.05	
N-P ET	63.37	0.91	70.12	74.08	57.33	0.03	0.06	0.12
01-Jul-2002 to 30-Sep-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	18.24	0.66	-41.87	82.49	84.48	0.16	0.35	
N-P	47.69	0.97	52.01	52.27	39.2	0.82	0.59	
N-ET	21.27	0.75	-32.21	70.87	74.72	0.34	0.44	
N-P ET	55.47	0.92	76.8	78.85	63.4	0.52	0.38	0.06
01-Jul-2003 to 30-Sep-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	70.17	0.77	0.07	48.01	56.66	0.59	0.38	
N-P	67.26	0.91	-4.08	35.65	46.67	0.72	0.54	
N-ET	70.63	0.76	0.72	48.14	57.38	0.58	0.38	
N-P ET	66.65	0.88	-4.95	34.08	49.85	0.68	0.56	0.25
01-Jul-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	125.15	0	99.06	173.83	175.32	-2.12	-0.74	
N-P	92.13	0.87	46.54	60.88	62.82	0.6	0.39	
N-ET	123.16	-0.02	95.9	170.44	172.52	-2.02	-0.71	
N-P ET	93.88	0.81	49.32	69.07	66.74	0.55	0.31	0.63

Deer Creek								
01-Jul-2001 to 30-Sep-2001								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	32.31	0.52	-29.87	30.16	23.45	-0.15	-0.02	
N-P	43.23	0.47	-6.16	23.44	20.09	0.16	0.21	
N-ET	37.42	0.54	-18.77	27.52	20.35	0.14	0.07	
N-P ET	46.01	0.48	-0.11	24.28	19.86	0.18	0.18	0.46
01-Jul-2002 to 30-Sep-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	33.39	0.65	78.01	92.44	19.55	-0.35	-0.82	
N-P	39.17	0.7	108.83	121.98	23.97	-1.03	-1.41	
N-ET	35.01	0.59	86.64	100.17	22.4	-0.77	-0.98	
N-P ET	40.21	0.62	114.35	125.17	25.55	-1.3	-1.47	0.63
01-Jul-2003 to 30-Sep-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	161.19	0.49	-9.15	36.3	130.05	0.23	0.07	
N-P	176.28	0.86	-0.65	29.92	94.37	0.59	0.23	
N-ET	173.33	0.47	-2.31	33.56	134.19	0.18	0.14	
N-P ET	188.45	0.88	6.21	33.81	102.3	0.52	0.14	0.65
01-Jul-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	280.62	0.49	64.3	94.81	273.61	-1.43	-0.71	
N-P	179.75	0.69	5.25	37.56	128.12	0.47	0.32	
N-ET	216.93	0.46	27.01	66.17	163.22	0.14	-0.19	
N-P ET	216.07	0.65	26.51	52.64	155.5	0.21	0.05	0.59

# Performance during Summer 7/1-9/30

Little River								
01-Jul-2002 to 30-Sep-2002								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	6.06	0.57	56.93	139.77	11.95	0.3	0.02	
N-P	4.67	0.71	20.96	101.51	10.29	0.48	0.29	
N-ET	4.71	0.57	21.94	123.53	11.93	0.31	0.14	
N-P ET	5.18	0.68	34.06	122.88	10.81	0.43	0.14	0.87
01-Jul-2003 to 30-Sep-2003								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	188.57	0.65	63.24	114.48	200.48	0.33	-0.08	
N-P	196.88	0.69	70.42	94.99	268.6	-0.2	0.11	
N-ET	217.98	0.74	88.69	122.41	194.79	0.37	-0.15	
N-P ET	185.32	0.7	60.42	86.09	265.03	-0.17	0.19	1
01-Jul-2004 to 30-Sep-2004								
Scenario	Mean	R	%M erro	%M abs	RMSE	E	E1	R(ET)
Default	251.41	0.17	146.88	169.75	287.44	-4.67	-1.07	
N-P	107.12	0.69	5.19	48.66	97.18	0.35	0.41	
N-ET	308.61	0.18	203.04	222.06	374.62	-8.62	-1.71	
N-P ET	100.37	0.71	-1.44	43.94	86.3	0.49	0.46	1

Overall:

NLDAS P shows advantage

Noah ET does not have a clear edge.

# Discussion

- Is current methods OK? If not, how can we improve it?
  - Implementing NLDAS ET
    - Setting LZETP=1 is simple
    - The later calibration method is more sophisticated but introduce more uncertainty.
  - PEST calibration
    - Use CBP parameters to start a good idea?
    - Are there better method than simply balancing each objective function components?
    - Use more or less parameters (fix those that is unlikely to change in this region)
- Ftable:
  - Got some data from MD USGS, could implement it for the next runs?
- Without big change, the results are unlikely to change.

# **Use of Landsat and MODIS to Predict Water Quality**

## **Application of NASA Satellite Products and Land Surface Models to Improve the Hydrologic Performance of the EPA's BASINS DST**

*Brenden McNeil, Phil Townsend, Kirsten deBeurs, Clayton  
Kingdon, and Keith Eshelman*

**Philip A. Townsend**

University of Wisconsin

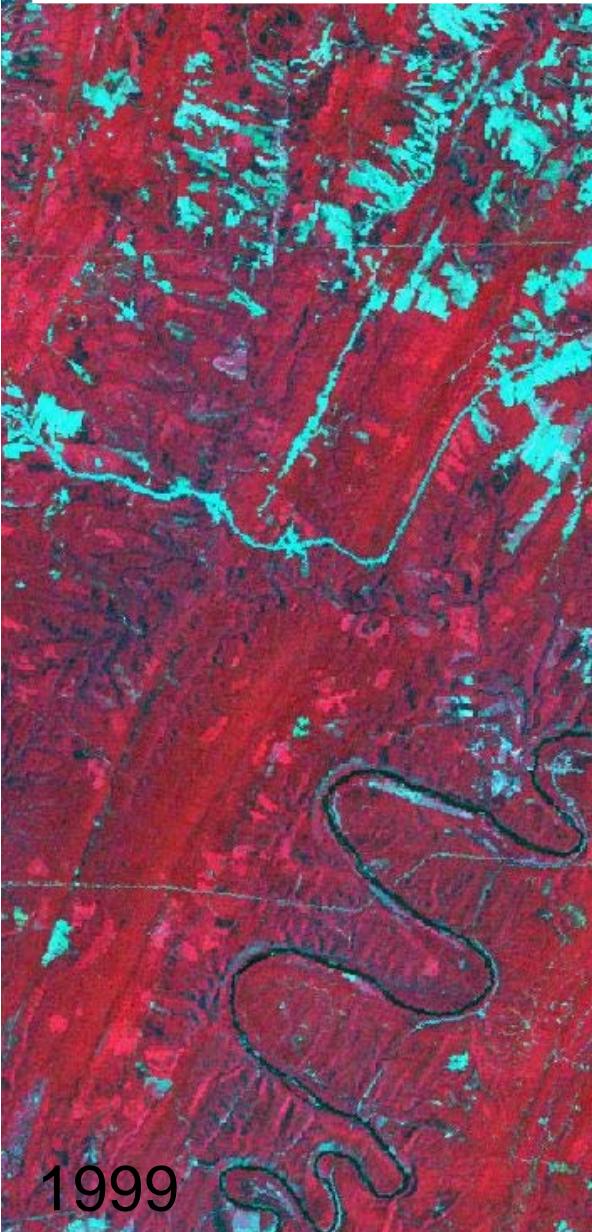
# Watershed Hydrology and Watershed Ecology

- Catchment
  - fundamental hydrologic unit
  - hydrologic cycle integrates physical and biological processes at/above/below the surface
- What remote sensing provides...
  - spatially explicit measurements of surface properties related to hydrology of the watershed
    - water budget (quantity)
    - water quality
  - information on changes in the functioning and status of ecosystems within the watershed

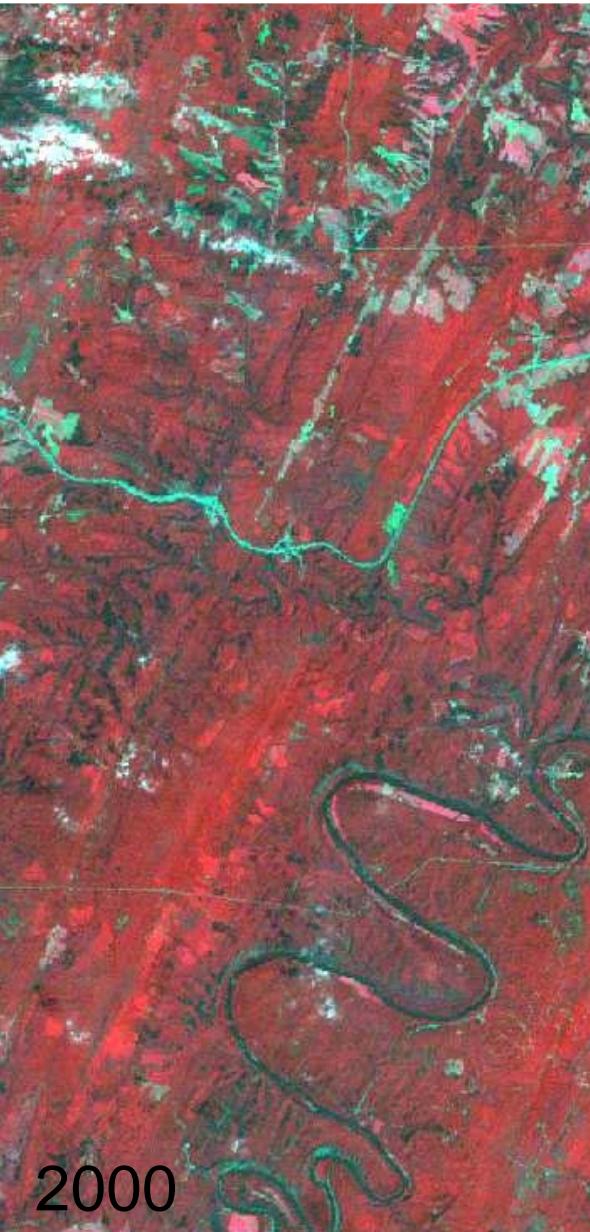
# Chesapeake Bay Watersheds

- Forests are the dominant land use in the Chesapeake Bay watershed.
- Forests generally have low nutrient yields per unit area.
- Small watershed studies suggest that disturbance is the primary cause of N leakage from forested watersheds to surface waters.

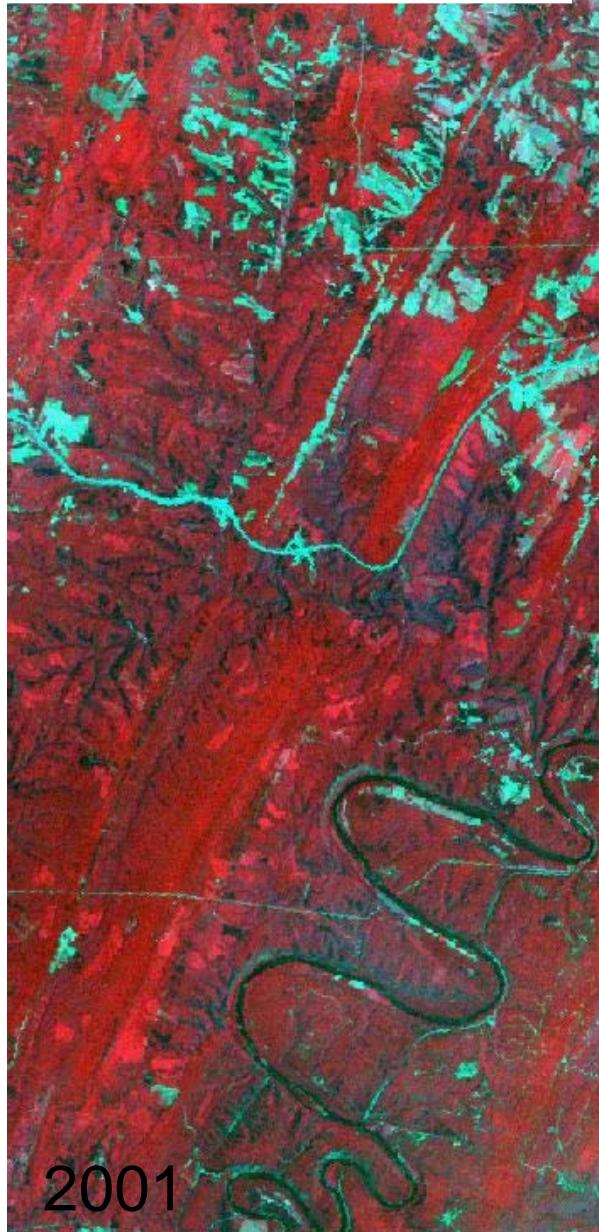
What remote sensing offers: time series of data that can be analyzed and interpreted in a consistent manner.



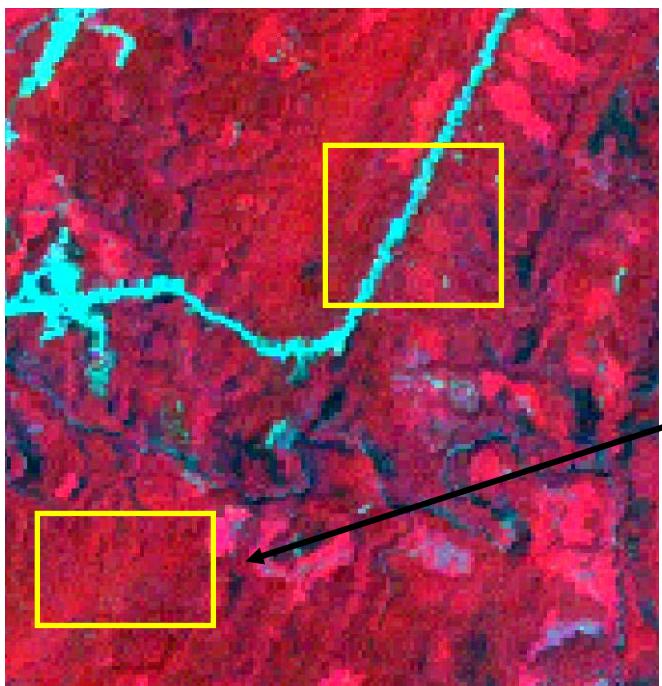
1999



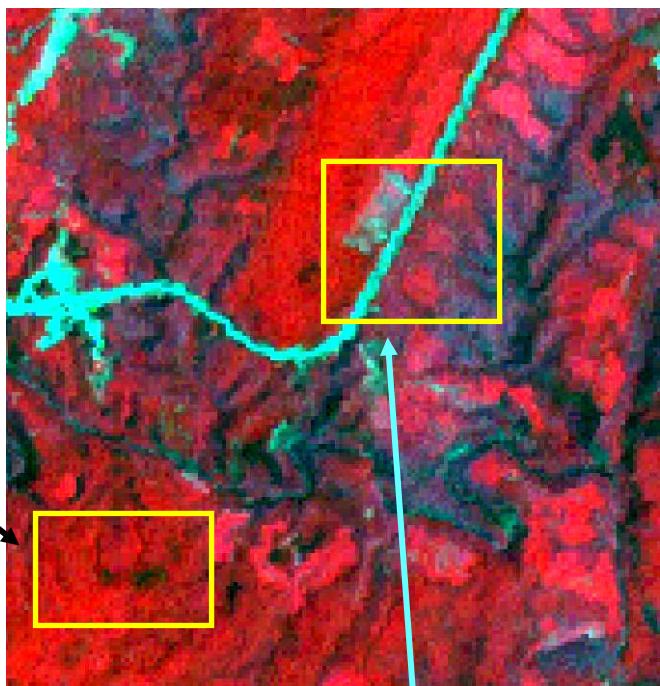
2000



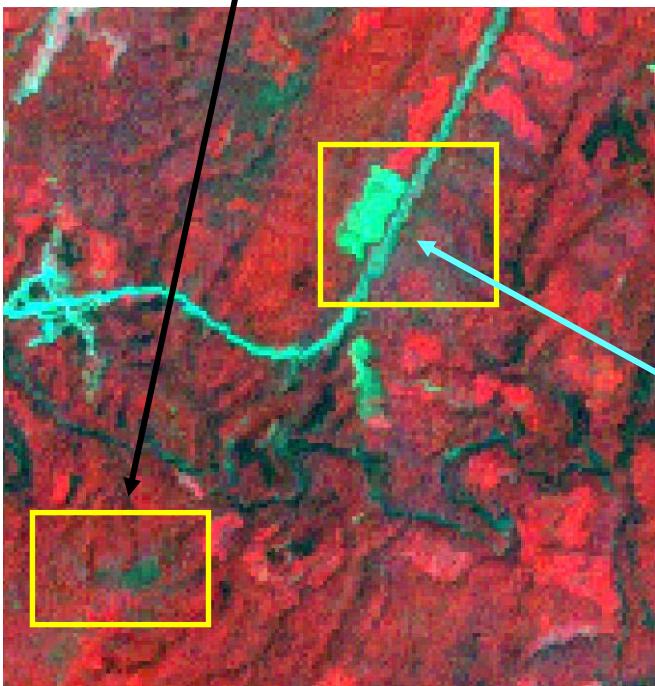
2001



Gypsy moth  
defoliation  
and forest  
mortality.



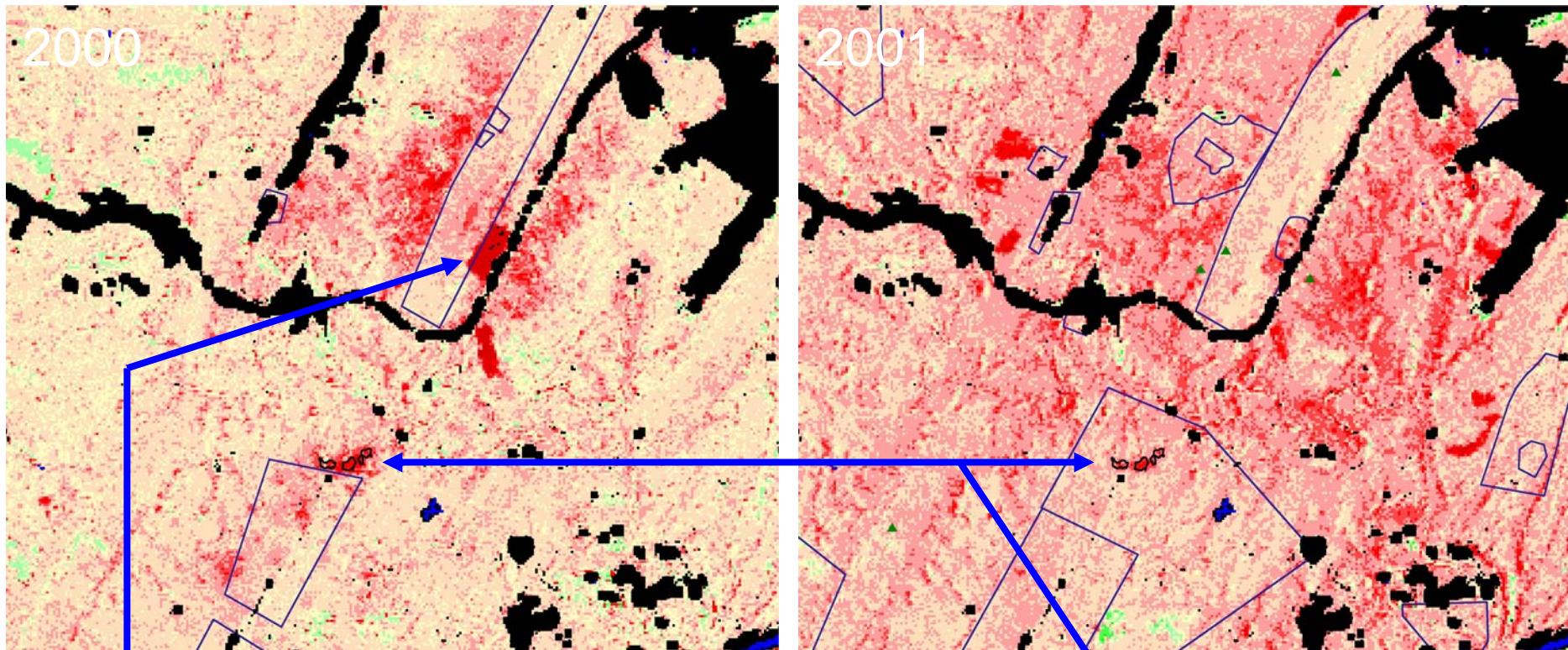
1999



2000

2001

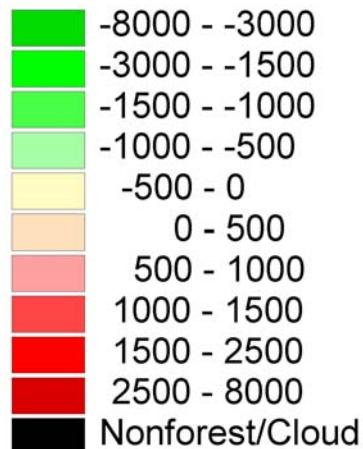
Logged area  
with regrowth.



Clearcut: estimated loss of biomass  
5000 – 7000 kg/ha.

Compare to estimates for region of  
foliar biomass: 3500 – 6000 kg/ha.

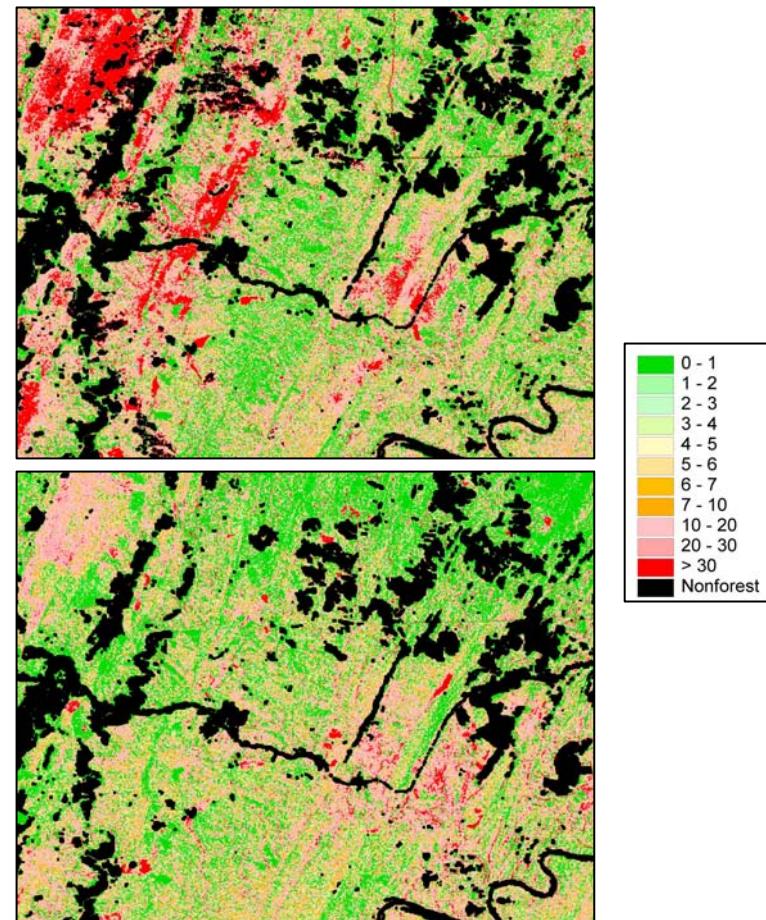
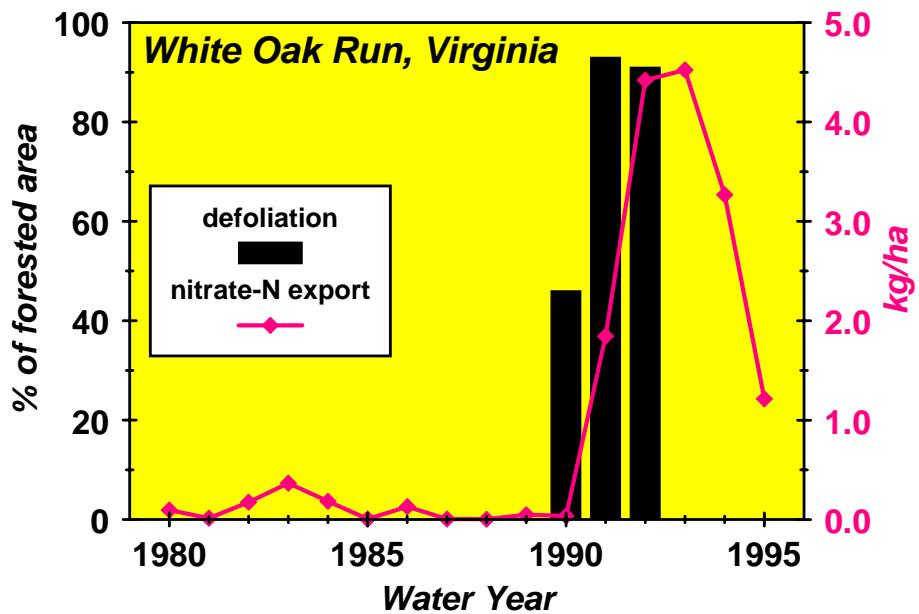
Areas of forest mortality.



# NASA-EPA Nonpoint Source Water Quality Remote Sensing of Land Cover (Univ. Wisconsin & UMCES)

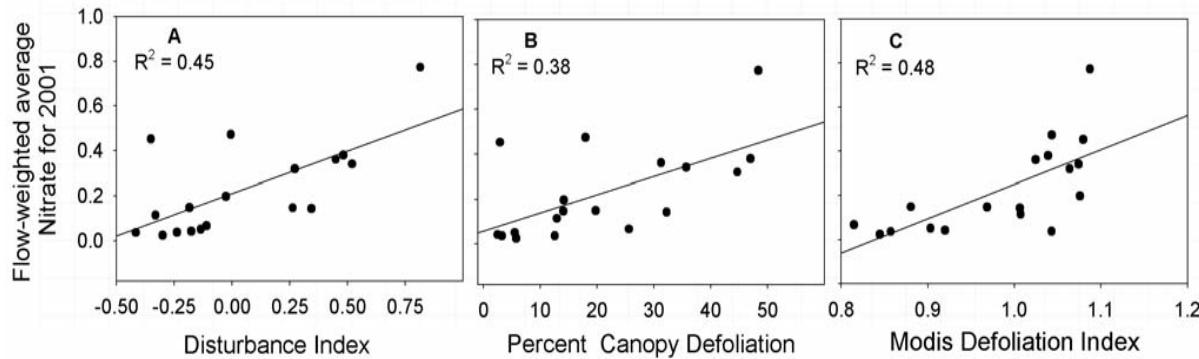
- Land Cover Disturbance from Gypsy Moths and Logging
- Satellite-Derived Measurements (MODIS / Landsat) of Disturbance, Link to Measures of stream nitrate concentration

## Gypsy Moth Defoliation & Annual Nitrate-N Export

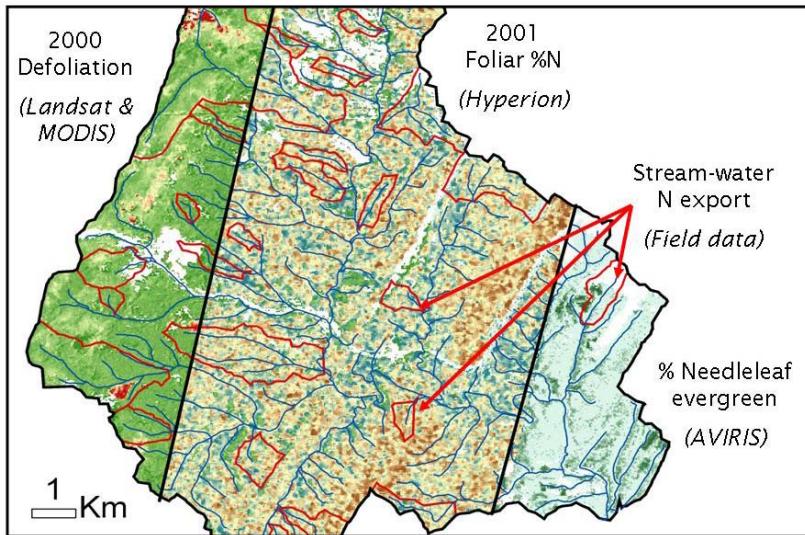


Estimated N deposition from gypsy moth frass for Allegany County, MD in 2000 (top) and 2001 (bottom) in kg/ha/yr.

# NASA-EPA Nonpoint Source Water Quality Remote Sensing of Land Cover (Univ. Wisconsin & UM CES)



Empirical relationships predicting watershed N export from three remote sensing spectral indices.



Partial representation of the data available in the Fifteen-mile Creek watershed of western Maryland to examine mechanisms driving the observed empirical relationships among forest disturbance and water quality.

# Conclusions

- The VERIFICATION component is demonstrated by the results of the default runs.
- The VALIDATION component was realized in a meeting with EPA in which the results were presented and it was agreed that such enhanced DST results would meet EPA's functional needs with the BASINS DST.
- Completing the V&V component provides a solid and defensible foundation for the BENCHMARK in which enhanced DST performance can be measured against the baseline statistics from the default runs.